III. FLOOD/DAM FAILURE

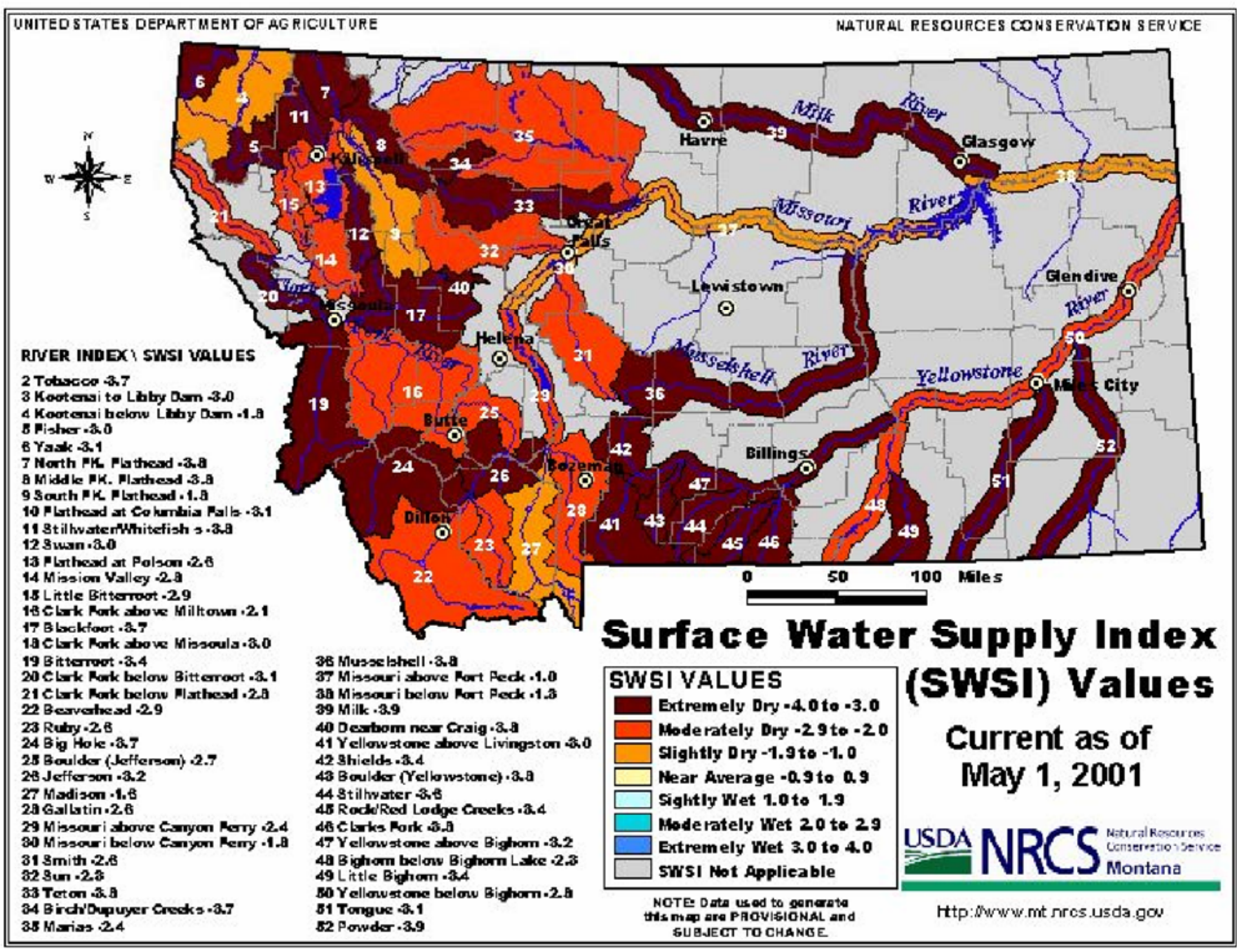
A. MONTANA FLOOD/DAM FAILURE OVERVIEW

B. DESCRIPTION

Floods constitute one of the most destructive natural hazards facing Montana. Flooding occurs when abnormally high stream flow overtops the natural or artificial banks of a water course (Hays, 1981).

Flood damage results primarily from the continued encroachment by man on floodplains (National Science Foundation, 1980). A floodplain is described as the combined area of the floodway and floodway fringe. The term floodway refers to the central portion of the floodplain that contains the stream and enough of the surrounding land to enable floodwaters to pass without increasing flood depths upstream (FEMA, 1986).

FIGURE 1: Surface Water Supply Index Map as of May 1, 2000.



The most severe damage to persons and/or property occurs in this zone. The area beyond the floodway in which water does not actively flow or flows at a minimal rate during a flood, or where standing water accumulates is considered the floodway fringe. Although the force of floodwaters in the floodway fringe is likely to be less destructive, property damage may be more extensive because most floodplain development is located in this fringe area (Jim E. Richard Consulting Services et al, 1986).

A flood's magnitude is expressed as the frequency with which a flood of a given volume is expected to occur. The 100-year flood is used as the standard for defining the flood hazard for development. A flood of this magnitude would be expected to occur once every 100 years or have a one percent chance of occurring during any year. The Federal Emergency Management Agency (FEMA) and the Montana Department of Natural Resources and Conservation delineate the boundaries of the 100-year floodplain on maps to provide assistance in planning and managing associated development (Jim E. Richard Consulting Services et al, 1986).

There are three principal types of floods, which may affect Montana: riverine floods, flash floods, and dam break floods. Riverine floods result from precipitation over large areas and/or from snowmelt. This type of flood occurs in river systems whose tributaries may drain large geographic areas and include many independent river basins. The duration of riverine floods may vary from a few hours to many days. Factors that directly affect the amount of flood runoff include precipitation amount, intensity and distribution, the amount of soil moisture, seasonal variation in vegetation, snow depth and water-resistance of the surface due to urbanization.

The term "flash floods" describes local floods of great volume and short duration. In contrast to riverine flooding, this type of flood usually results from a torrential rain on a relatively small drainage area. Precipitation of this sort usually occurs in the summer. The sudden break-up of an ice jam or the failure of a dam may also result in flash flooding. Flash floods are a potential threat to life and property in areas characterized by steep terrain, high surface runoff rates, and narrow canyon streams and/or subject to severe thunderstorms.

Flooding may also result from the failure of a dam. Dam break floods are usually associated with intense rainfall or prolonged flood conditions. The greatest threat to people and property is normally in areas immediately below the dam since flood discharges decrease as the flood wave moves downstream. Dam failure may be caused by faulty design, construction and operational inadequacies, or a flood event larger than the design flood (Hays, 1981). The degree and extent of damage depend on the size of the dam and the circumstances of failure. A small dam retaining water in a stock pond may break resulting in little more damage than the loss of the structure itself. In contrast, a dam break could result in the loss of irrigation water for a season causing extreme financial hardship to many farmers. An even larger dam failure might bring about considerable loss of property, destruction of cropland, roads and utilities and even loss of life. Consequences that are more far-reaching can include loss of income, disruption of services and environmental devastation (LaFrance, 1984).

C. HISTORICAL OCCURRENCE AND RESPONSE

All three types of floods just described (riverine floods, flash floods and dam failure floods) have occurred in Montana's main river basins (see Figure 2). The counties that received Presidential disaster declarations from 1964 to 1986 due to flooding are shown in Figure 3. The following discussion will give historical examples of each flood type. The reader should realize that there is some overlap between the flood types.

The Flathead River in the Columbia River Basin has been subject to numerous significant flooding events over the years (see Table 1). A June flood in Missoula County in 1908 involved nearly every major stream and river. This event was the result of unseasonably warm temperatures and thirty-three (33) consecutive days of rain (Henry, 1987). In June 1964, approximately fifteen (15) inches of rain accumulated over a (30) thirty-hour period in the upper Flathead drainage. The resulting flood damaged more than 350 houses near Kalispell. The Corps of Engineers estimated that the damages in the Flathead Basin totaled $25 million. In January 1974, the counties of Lincoln, Sanders, Flathead, Glacier, Mineral, Missoula and Deer Lodge were hit by flood waters which caused approximately $16 million worth of damage to Forest Service roads, bridges and facilities, private property, etc. These same counties suffered flood related losses again in June 1975, totaling nearly $35 million (Montana Civil Defense Division, 1976).

For over 100 years, the U.S. Geological Survey has been monitoring stream flow in Montana with support from Federal, State, and local Cooperators. The information in Table was taken from the following web page, which monitors Montana stream flows, and historical flood flows to the 100-year event. http://montana.usgs.gov/rt-cgi/gen_tbl_pg.

TABLE 1: History of flooding in the Columbia River Basin (see bottom Table 3 for sources and web site http://montana.usgs.gov/rt-cgi/gen_tbl_pg

SOURCE OF FLOODING	URBAN AREAS IMPACTED	YEARS OF FLOOD EVENTS
Middle Fork Flathead R.	W. Glacier, Nyack	1948, 1954,1964, 1972, 1975,1991
Kootenai R.	Libby, Troy	1916, 1948, 1974 1975,1976, 1981
Stillwater R.		1947,1948, 986,1996, 1997
Big Cherry Creek.	Libby	1948, 1964, 1972, 1975, 1976, 1981, 1996, 1997
Flower Creek.	Libby	Same as Cherry Ck
Libby Creek.	Libby	Same as Cherry Ck
Parmenter Creek.	Libby	Same as Cherry Ck
Flathead R.	Flathead Valley	1894, 1928, 1933-nearly every year since
Clark Fork R.	Thompson Falls	1908, 1948, 1964, 1975, 1981, 1997
Drummond, Clinton,		1974, 1975, 1981, 1995, 1996, 1997, 1998, 1999
Yaak	Troy	1948, 1954, 1956, 1967, 1986, 1997
Little Blackfoot	Garrison	1974, 1975, 1980, 1981, 1996
Jocko R.		1964, 1985, 1987, 1989, 1992, 1997
Bear Creek.		1964, 1975
Ashley Creek.		1947, 1948,1986, 1991, 1996, 1997
Rattlesnake Creek.		1908, 1948, 1974
Blackfoot R.	Lincoln, Missoula	1908, 1927, 1964, 1972, 1974, 1975, 1996, 1997

SOURCE OF FLOODING	URBAN AREAS IMPACTED	YEARS OF FLOOD EVENTS
Pattee Creek.	Missoula (So. Hills)	1962, 1964, 1967, 1976, 1980, 1986, 1996, 1997
Camp Creek.	Philipsburg	1974, 1978, 1986, 1996
Frost Creek.	Philipsburg	1972, 1974, 1986, 1996
Edwards Gulch	Drummond	1974, 1986, 1996
Flint Creek.		1943, 1986, 1996, 1997
Rock Creek.	Clinton	1927, 1972, 1975
Little Blackfoot R.	Elliston, Avon	1981, 1986, 1996, 1997
Cottonwood Creek.	Deer Lodge	1908, 1916, 1917, 1928, 1948, 1964, 1975, 1981, 1986, 1997
Warm Springs Creek.	Anaconda	1948, 1958, 1965, 1967, 1974, 1986, 1996, 1997
Bitterroot R. Florence, Hamilton	Bell Crossing, Darby	1899, 1908, 1947, 1948, 1972, 1974, 1996, 1997

The most damaging flood in the Missouri River Basin occurred in June 1964 (see Table 2). The principal rivers involved were the Dearborn, Sun, Teton and Marias. The event was initiated by eight to ten inches of rain over three days on a deeper than average snow pack. All counties situated along the Continental Divide were affected to some degree. However, the greatest damage was received by the City of Great Falls. This disaster resulted in the loss of (30) thirty lives and an estimated $55 million in damages. The Corps of Engineers recently completed a $12 million dollar flood control levee along the north bank of the Sun River near Great Falls, which protects over 500 homes and businesses (Henry, 1987).

The combination of snowmelt and spring rains with frequent ice jams causes flooding on the Beaverhead River near Dillon. During the most recent flood, 1984, crews successfully prevented major damage by channeling floodwaters through town on streets lined with sandbags and straw. The Clark Canyon Dam above Dillon and emergency dikes built on the river near town reduced potential damages (Henry, 1987).

TABLE 2: History of flooding in the Missouri River Basin.

SOURCE OF FLOODING	URBAN AREAS IMPACTED	YEARS OF FLOOD EVENTS
Missouri R. (Mainstream)	Great Falls to Ft. Benton	1948, 1953, 1964, 1975, 1981, and 1986
Dearborn R.	Great Falls	1894, 1899, 1908, 1916, 1927, 1936,1948, 1953, 1958,1964, 1965, 1966,1969, 1975, 1981,1986, 1996, 1997
Sun R.	Great Falls, Augusta and Simms	1948, 1953, 1964, 1975, 1981, and 1997
Teton R.	Choteau, Ft. Benton	1908, 1916, 1948, 1953, 1964, 1975,1986, 1996, 1997
Elk Creek.	Augusta	1964, 1975, 1981, 1986, 1996, 1997
Spring Creek.	Choteau	1964, 1975, 1986, 1997
Muddy Creek.	Choteau, Vaughn	1964, 1975, 1986, 1996, 1997
Belt Creek.	Belt, Neihart	1908, 1953, 1981, 1996, 1997
Highwood Creek.	Highwood	1953
Blackfoot R.	Lincoln	1964, 1975, 1986
Marias R.	Shelby, Kevin	1948, 1953, 1964, 1975, 1986
Birch Creek.	Dupuyer	1964
Midvale Creek.	East Glacier	1964
Willow Creek.	Browning	1964
Dupuyer Creek.		1964, 1975, 1986
Cut Bank Creek.		1964, 1974, 1975, 1986
St. Mary R.	St. Mary	1964
Belly R.	Glacier National Park	1964
Waterton R.	Glacier National Park	1964
Milk R.	Glacier, Havre, Nashua Glasgow, Dodson Chinook, Harlem Malta, Saco	1880, 1888, 1899 1906, 1907, 1912 1917, 1922, 1925 1927, 1939, 1943, 1952, 1953, 1960, 1964,1978, 1979,

		1986, 1987, 1996, 1997
Big Spring Creek.	Lewistown	1920, 1947, 1953, 1964, 1975, 1986, 1996, 1997
S. Fork McDonald Creek.	Grass Range	1938, 1962, 1964, 1965, 1975, 1979

SOURCE OF FLOODING	URBAN AREAS IMPACTED	YEARS OF FLOOD EVENTS
Big Casino Creek.	Denton	1978, 1979
Ten-mile Creek.	Helena Valley, Helena	1908, 1938, 1953, 1964, 1975,1981, 1986, 1996, 1997
Seven mile Creek.	Helena Valley, Helena	1964
Prickly Pear	Helena Valley, East, Helena	1908,1964,1975 1981, 1986, 1996, 1997
Wolf Creek.	Wolf Creek	1964
Boulder R.	Boulder	1964, 1975, 1981
Smith R.		1981
Basin Creek.	Basin	1981
E. Gallatin R	Bozeman	1948, 1958, 1969, 1970, 1971, 1981
Rocky Creek.	Bozeman	1981
Bridger Creek.	Bozeman	1970, 1981
Cataract Creek.	Bozeman	1981
Hyalite Creek.	Bozeman	1981
Bear Canyon Creek.	Bozeman	1981
Bozeman Creek.	Bozeman	1893, 1937, 1947, 1948, 1958, 1960, 1969, 1970, 1974,1975, 1977
Mathew-Bird Creek.	Bozeman	1960
W. Gallatin R.		1952, 1959, 1963, 1970, 1971, 1974,1975, 1983, 1996, 1997
Jefferson R	Three Forks Area	1899, 1908, 1927, 1948, 1980, 1984, 1995, 1997
Madison R		Nearly every year before 1920 -- 1949, 1972,1975, 1978, 1983, 1990, 1996, 1997
Silver Creek.		1964, 1975
Blacktail-.Deer Creek.	Dillon	1964, 1984, 1996
Beaverhead R.	Dillon	1937, 1949, 1951, 1964, 1974, 1979, 1984, 1996, 1997

Significant floods have occurred on the Milk River and its tributaries primarily as a result of rapid snowmelt over frozen soil. Heavy rains caused the greatest flood on record for this river in April 1952; damages between Havre and the river's mouth below Nashua were in the millions of dollars. Levees offer limited protection to the communities of Havre, Chinook, Malta, Saco, Glasgow, and Nashua, however, several are in need of repair (Henry, 1987).

The Yellowstone River system is one of the remaining large rivers in this country that does not have a major flood control dam, with the exception of the Yellowtail Dam on the Big Horn River. Large floods have affected the Glendive area near the end of the Yellowstone River typically as a result of ice jams (see Table 3). Flooding in 1899 took four lives and destroyed a new bridge. The Corps of Engineers built a levee in 1959, which protects a portion of the town. Miles City, located at the junction of the Tongue and Yellowstone Rivers is one of the more flood prone towns in the state. Limited protection of the city is afforded by levees (Henry, 1987). Most recently was the extensive flooding in Park County near Livingston in 1996 and 1997.

Flash Floods

Flash flooding is common in some areas of the state during the summer storm season. The best examples of this type of flooding have occurred in the Billings area. Flooding of the tributaries of the Yellowstone has resulted from intense summer thunderstorms, typically short in duration, which produce high peak flows. Major flooding of this type occurred in 1923 and 1937 (Henry, 1987). Flash flooding is also common along drainages in Lincoln, Sanders, Flathead, Glacier, Mineral, Missoula and Deer Lodge Counties during the summer storm season (Montana Civil Defense Division, 1976).

TABLE 3: History of flooding in the Yellowstone River Basin.

SOURCE OF FLOODING	URBAN AREAS IMPACTED	YEARS OF FLOOD EVENTS
Yellowstone River	Livingston, Billings Miles City	1894, 1918, 1928, 1937, 1943, 1944, 1948, 1967, 1971, 1974, 1975, 1978, 1996, 1997
Yellowstone River	Glendive	1899, 1916, 1920, 1936, 1943, 1969, 1971, 1986, 1994, 1996
Tongue R.	Miles City	1882, 1887, 1888, 1892, 1899, 1902, 1909, 1912, 1918, 1923, 1928, 1929, 1944, 1949, 1969,1971, 1974, 1986,1996, 1997
Lone Tree Creek.	Sidney	1951, 1972, 1996, 1997
Lower Deer Creek.		1918, 1967
Powder R.	Broadus	1923, 1962, 1965, 1967, 1978, 1996
Little Bighorn R.	Hardin, Crow Agency	1969, 1971, 1978, 1982, 1996, 1997
Bighorn R.	St. Xavier	1978
Pryor Creek.	Pryor, Billings	1978
Italian Ditch	Laurel	1978
Stillwater R.	Countywide	1967, 1974, 1975, 1996, 19971978
Rock Creek.	Red Lodge	1952, 1957, 1967, 19961975, 1978
Boulder R.	Big Timber	1956, 1974, 1975, 1996, 1997

Sources for Tables 1, 2 and 3: Boner and Stermitz 1981-1985; FEMA, 1979, 1981-1985; Henry, 1987; Johnson and Omang, 1974; Johnson and Omang, 1976; Paulsen, 1949; Wells, 1955; Wells, 1957.

Dam Failure Floods

Dam failure floods in Montana have primarily been associated with riverine and flash flooding. Never the less, the potential for a major flood occurring solely as a result of dam failure is a real possibility. The loss of thirty (30) lives during the 1964 flood in the Missouri River Basin was due primarily to the sudden failure of Swift Reservoir on Birch Creek and Two Medicine Dam on Two Medicine Creek. There was no time to warn residents in the creek valley below. During the 1952 flooding of the Milk River, Frenchman Dam on Frenchman Creek failed. This caused the highest peak ever recorded on the Milk River below its confluence with Frenchman Creek (Henry, 1987).

In 1927, Pattengail Creek Dam in Beaverhead County failed causing four known deaths and near complete destruction of the towns of Dewey and Wise River. More recently, June 20, 1984, Browns Lake Dam, also located in Beaverhead County, was overtopped resulting in washed out roads and bridges downstream. Estimated property damage amounted to $100,000 (LaFrance, 1984).

D. PREDICTION POTENTIAL FOR RECURRENCE

History has shown that floods are natural and recurrent events. On the basis of present knowledge, the size, time and location of flooding is difficult to predict in advance (Hays, 1981). When discussing flood recurrence potential both long-term and short-term predictions must be taken into consideration. The following information is necessary in order to make long-term predictions of potential flooding in a jurisdiction:

1) Potential sources of flooding which affect the jurisdiction. All streams, rivers, canals and reservoirs within the jurisdiction have the potential to contribute to a flood.

2) Potential causes of flooding from each source. Rainfall, snowmelt and dam failure are the primary factors in initiating flooding.

3) Likely characteristics of flooding from each source. These include magnitude, speed of onset, season of occurrence and depth (FEMA, 1983). As discussed earlier, a flood's magnitude is expressed as the frequency with which a flood of a given volume is expected to occur (Jim E. Richard Consulting Services et al, 1986). The probability of occurrence of floods of various magnitudes at a site may be determined by statistical analysis of annual peak discharges for all years of record at that site. Annual peak discharge is the highest rate of flow in a stream in a twelve-month period. A common practice is to refer to a peak discharge of a given magnitude in terms of its return period. For example, a peak discharge that has a two-percent chance of occurring during any year would be expected to occur once in 50 years. The speed of onset is the amount of time that passes between flood warning and impact on a community. This would depend on the type of floods a jurisdiction might experience. A community situated below a dam or in an area that is subject to flash flooding can expect a rapid speed of onset. History should indicate the seasonality and depth of floods characteristic of an area (FEMA, 1983). Flooding may take place in all seasons: fall/winter floods due to rainfall and temperature patterns; spring floods from snowmelt, ice jams or seasonal rainfalls; summer flooding due to thunderstorms which affect small areas (Hays, 1981). The heaviest precipitation in Montana occurs between April and September. The mountain snow pack begins to melt in April and usually reaches a peak

in late May or early June. Runoff is essentially completed in July. Annual peak discharges normally occur in late March or early April. Later increases in stream flow are dependent upon rain of sufficient intensity and duration to cause surface runoff (MDNRC, 1976).

The information listed in 1, 2 and 3 above is often available from various government agencies (see listing under Mitigation, this section). Emergency managers equipped with the above information would be far more knowledgeable about flooding potential in their jurisdictions. Possessing the information necessary to make long-term flood predictions enables an emergency manager to institute effective flood mitigation techniques.

Short-term flood prediction potential does not allow much time for enacting mitigation measures, however, it may be critical in saving lives and reducing property damage. Chief sources of information for predicting an impending flood include:

1) Rainfall forecasts, radar information, satellite imagery and comprehensive data available from the National Weather Service.

2) Upstream rainfall and stream flow measurements, collected by observers or automated equipment.

3) Reports of upstream flows and flooding from other communities, state police and other sources (FEMA, 1983).

Much of the information necessary to assess an area's potential for flooding will also give some indication of area vulnerability to flooding.

E. STATE VULNERABILITY TO FLOODING

Flooding becomes a hazard when people compete with nature for the use of floodplains. If floodplain areas were left in their natural state, flooding would not cause major damage. Urban, industrial and other surface development in natural floodplain areas of Montana has increased the vulnerability to serious flooding. The extent of artificial surface area created by development prevents rainfall from soaking into the ground and increases the rate of runoff (National Science Foundation, 1980).

As stated previously, Montana is vulnerable to riverine and flash flooding, and dam failure floods.

Riverine and Flash Flooding

Since the major differences between riverine and flash flooding relate to speed and season of onset rather than impacted areas, these two types of flooding will be addressed here as one.

It is difficult to assess area specific vulnerability to flooding at the scale of this analysis. Any area, through which a water course flows, may be vulnerable to flooding. Those areas, which have been subject to past flooding, are the most likely to be vulnerable in the future. The Historical Occurrence and Response subsection noted some examples of past flooding including those that caused damage of such proportions as to warrant Presidential disaster declarations. These areas will undoubtedly be subject to flooding again. The potential impact is compounded as development continues to encroach upon floodplains.

Based on the above knowledge the logical items of information to consider in assessing the State's vulnerability to flooding are location of water courses, historical flooding events, and population distribution. Figure 4 shows the major water features in Montana. The combination of this map with the population distribution overlay (found in the back pocket of this binder) reveals areas where population settlement and floodplains probably overlap. This overlap represents a potential hazard. If these areas have experienced flooding in the past their vulnerability to future flooding should be considered high. Continued development will naturally increase that vulnerability.

NOTE: MAJOR WATER FEATURES MAP

Local emergency managers can refine this information by studying the situation more closely for their jurisdiction. Maps that outline floodplains and/or flood hazard areas in most jurisdictions are available from the Flood Plain Management Section of the Montana Department of Natural Resources and Conservation, the Federal Emergency Management Agency, the Soil Conservation Service and the U.S. Geological Survey (FEMA, 1983). It is critical that the emergency manager determine site-specific vulnerability in order to effectively implement mitigation strategies.

Dam Failure Flooding

The Water Projects Bureau administers the operation and maintenance of state-owned water projects. These include 22 dams, with approximately 300 miles of irrigation canals and one 10 MW hydropower facility. The bureau is also responsible for dam safety of 10 dams owned by the Department of Fish, Wildlife, and Parks. Most of the DNRC projects are operated by local water users associations that use the water for irrigation. Many of the projects provide secondary recreational benefits including camping, fishing and boating.

State-Owned Water Projects

Name	Year Completed	Storage (acre-feet)	Height (feet)	County
*Ackley Lake Dam	1938	5,815	51	Judith Basin
*Bair Reservoir Dam	1939	7,010	102	Meagher
*Cataract Dam	1959	1,478	80	Madison
*Cooney Dam	1937	28,400	102	Carbon
*Cottonwood Dam	1953	1,900	39	Park
*Deadmans Basin Dam	1941	72,220	60	Wheatland
*East Fork of Rock Creek Dam	1938	16,040	83	Granite
Fred Burr Dam	1948	516	50	Ravalli
Frenchman Dam	1952	3,750	44	Phillips
*Glacier Lake Dam	1937	4,200	57	Carbon
*Martinsdale Dam	1939	23,110	91	Wheatland
*Middle Creek Dam (Hyalite)	1951	10,184	125	Gallatin
*Nevada Creek Dam	1938	12,640	88	Powell
*Nilan Dam	1951	10,090	54	Lewis & Clark
*North Fork of Smith River Dam	1936	11,406	84	Meagher
*Painted Rocks Dam	1940	32,362	143	Ravalli
*Ruby River Dam	1939	36,633	111	Madison

*Tongue River Dam	1939	79,071	94	Big Horn
*Toston Dam (Broadwater-Missouri)	1940	3,000	56	Broadwater
*Willow Creek Dam	1938	17,730	105	Madison
Yellowater Dam	1938	3,840	37	Petroleum

Department of Fish, Wildlife and Parks Dams

Name	Year Completed	Storage (acre-feet)	Height (feet)	County
Ashley Lake		20,400	10	Flathead
*Bearpaw Dam	1958	535	59	Hill
Clearwater Fish Barrier	1963	less than 50	15	Missoula
*Gartside Dam	1962	326	30	Richland
Johnson Reservoir	1930s	208	23	Hill
Knowlton Reservoir	1890-1910	166	15	Teton
South Sandstone Reservoir	1975	940	38	Fallon
Whitetail Dam	1930s	198	21	Daniels
*Park Lake Dam	1872	225	22	Jefferson
Rainy Lake Fish Barrier				Missoula

* Denotes High-Hazard Dams: A "high-hazard" dam is one whose failure would endanger lives.
This classification is not a reflection on the actual condition of the dam.

There are a number of concrete and earth fill dams throughout the state designed for power and/or irrigation that present potential flood problems (MT Civil Defense Division, 1976). Some of these dams are considered unsafe for various reasons. Many are considered unsafe due to improper operation and poor maintenance (LaFrance, 1984). Some were not designed to withstand even half the flow expected to occur during severe flooding without overtopping the dam. Other improper design and construction methods such as adding a few feet of earth to the top of an existing dam to increase storage capacity could lead to greater risk and magnitude of failure.

Vulnerability to dam failure flooding is compounded by the fact that the false sense of security created by an upstream dam encourages settlement in the flood hazard area below the dam (National Science Foundation, 1980). Extreme events could exceed the flood storage capacity of even large reservoirs. At such times, the excess water passed over the spillway (the primary purpose of which is to protect the dam) may cause damages downstream which could approach those that would have occurred had the dam not been built. However, the failure of a dam could produce flood rates and damages in excess of that which would have resulted if the dam had not been built (Committee on Safety Criteria for Dams et al, 1985).

In 1981, the United States Army Corps of Engineers completed inspection of non-federal dams in Montana. Generally, the Corps inspected dams that were at least twenty-five (25) feet high or impounded at least fifty (50) acre-feet of water and were located upstream from populated areas or areas where dam failure could cause serious property damage. Thirty-six (36) dams received unsafe classifications and deficiencies were found in all other dams inspected (U.S. Army Corps of Engineers, 1981). Since that time, three of the thirty-six (36) have been breached and one has been rehabilitated (McDonald, 1987). Table 4, lists those dams classified as unsafe while Figure 5, graphically locates them. The most common problem identified was an inability to safely handle flood flows (U.S. Army Corps of Engineers, 1981).

TABLE 4: Non-federal dams classified as unsafe by U.S. Army Corps of Engineers:

Name	County	River	Date of * Report
1. Lima	Beaverhead	Red Rock River	07-25-80
2. Tongue River Dam	Big Horn	Tongue River	12-15-80
3. Storm Lake Dam	Deer Lodge	Storm Lake Creek	06-25-81
4. Lower Baker Dam	Fallon	Sandstone Creek	06-27-79
5. South Sandstone Creek Dam	Fallon	South Sandstone Creek	04-30-81
6. Big Casino Creek Dam	Fergus	Big Casino Creek	03-27-81
7. East Fork Dam	Fergus	East Fork Big Spring	03-27-81
8. Hanson Creel Dam	Fergus	Hanson Creek	03-27-81
9. Pike Creek Dam	Fergus	Pike Creek	03-27-81
10. Middle Creek Dam	Gallatin	Hyalite Creek	07-11-80
11. Lower Willow Creek Dam	Granite	Lower Willow Creek	02-25-81
12. Beaver Creek Reservoir Dam	Hill	Beaver Creek	03-26-81
13. Delmoe Lake Dam	Jefferson	Big Pipestone Creek	05-15-80
14. Big Sky Dam	Madison	Middle Fork, West Fork, Gallatin River	04-09-81
15. Cataract Creek Dam	Madison	Cataract Creek	07-22-80
16. Lower Branham Dam	Madison	N. Fork Mill Creek	02-27-81
17. Ruby Dam	Madison	Ruby River	08-02-80
18. Willow Creek Dam	Madison	Willow Creek	08-13-80
19. Bair Dam	Meagher	N. Fork Musselshell River	03-11-81
20. Hanson Reservoir Dam	Meagher	Woods Gulch Creek	03-25-81
21. Newlan Creek Dam	Meagher	Newlan Creek	05-04-81
22. N. Fork of Smith River Dam	Meagher	North Lake Smith River	05-08-81
23. Voldseth West Dam	Meagher	Tr-Comb Creek	10-31-80
24. Wallace Creek Dam	Missoula	Wallace Creek	04-29-81
25. Cottonwood Dam	Park	Cottonwood Creek	03-04-81
26. Petrolia	Petroleum	S. Fork Flatwillow Creek	01-16-81
27. Yellow Water Dike	Petroleum	Yellow Water Creek	10-22-80
28. Yellow Water Main	Petroleum	Yellow Water Creek	10-22-80
29. Nevada Creek Dam	Powell	Nevada Creek	01-29-81
30. Vaux No. 1	Richland	Lone Tree Creek	03-04-80
31. Vaux No. 2	Richland	Lone Tree Creek	03-04-80
32. Tin Cup Lake Dam	Ravalli	Tin Cup Creek	09-09-81

***** Personal communication with Glen McDonald, Project Rehabilitation Supervisor, DNRC, on March 19, 1987, confirmed that the dams listed here are still considered unsafe (i.e., sufficient repair has not taken place to date to remove them from the unsafe category).

NOTE: FIGURE 5 LOCATION OF UNSAFE DAMS MAP GOES HERE

F. MITIGATION

Although floods are not subject to complete control by man, they do occur in areas that can be defined with a fair degree of accuracy. Theoretically then, it is possible to reduce potential damage through the selection and implementation of various mitigation techniques. Past mitigation has ranged from warnings and preventive measures before a flood (e.g., dams, levees, etc.), to costly relief and rehabilitation afterward (National Science Foundation, 1980). Current mitigation techniques are far more diverse and attempt, where possible, to avoid the problem rather than merely treat the symptoms of the problem.

Some flood hazard mitigation techniques apply to all three flood types previously reviewed. These techniques will be discussed first followed by mitigation strategies, which apply directly to dam failure.

Flood hazard mitigation strategies are generally classified as either non-structural or structural. The distinction is not always clear. Non-structural measures generally attempt to modify susceptibility to flood damage through such means as regulatory and administrative approaches, while structural techniques usually employ engineering approaches to contain floods (FEMA, 1983).

Non-structural Mitigation

Non-structural mitigation techniques may be considered either preventive or corrective (see Table 5). Preventive actions are those, which are primarily directed toward vacant, undeveloped flood plains and which may be taken any time during either the pre- or post- disaster period. Corrective actions are those that attempt to mitigate flood damages that occur as a result of unwise development of flood hazard areas (FEMA, 1981).

TABLE 5: Non-Structural Flood Hazard Mitigation Techniques.
Relative Length of Time for Implementation

	Short Term	Mid-Term	Long-Term
Corrective Techniques			
1. Acquisition and Relocation		X	X
2. Flood proofing	X		
3. Structural Elevation	X		
4. Floodwalls and Levees		X	
5. National Flood Insurance Program (discussed only under preventive techniques)	X	X	
6. Disaster Contingency Planning	X		
7. Flood Forecasting & Warning Systems	X		
Techniques			
1. Research			
2. Information and Education	X		
3. National Flood Insurance Program	X	X	
4. Comprehensive Community Planning	X		
5. Regs to Control Floodplain Development			
a. Zoning ordinances			X
b. Subdivision regulations		X	
c. Building permits and building codes	X		
d. Soil erosion and sedimentation controls	X		
e. Storm water runoff controls	X		
6. Drainage and Flood Control Criteria		X	
7. Master Drainage way Planning		X	
8. Public Acquisition of Flood Prone Lands for Park, Recreation and Open Space Purposes		X	
9. Community Policy regarding provision of Public Facilities and Utilities in Floodplain Areas	X		

Preventive Techniques

1. **Research.** Flood mitigation strategies must be designed to meet the particular needs of the area to be served. Emergency managers should gain a thorough understanding of the flood problem and area at risk in their jurisdictions. Pertinent, site-specific information is often available from local, state and federal agencies. Volunteer organizations also provide sources of assistance. Some examples include weather and flood forecasting agencies, water resources agencies, Red Cross, emergency services, local assessors, local planning agencies, etc. Table 6, lists potential sources of federal assistance.

2. **Information and Education**. Once the necessary technical information on flood hazard potential has been researched an information and education program must be developed. Awareness by the general public, government officials, community decision-makers, planners and floodplain occupants, of the value of hazard mitigation and the benefits of floodplain management are necessary in order to gain their support.

Local officials should be encouraged to give the same attention and priority to drainage problems as to police and fire problems since flooding can take as many or more lives. The program should explain the nature of floods, the relationship between unwise development and damage, hazard mitigation options and available assistance (National Science Foundation, 1980). Methods of disseminating information include informational maps and brochures mailed to floodplain occupants, marking of public structures and bridges with the 100-year or historical flood level, warning signs, public service announcements on radio and television, and educational articles in local newspapers (FEMA, 1981).

TABLE 6: Available Federal Assistance for Program Development (Key at end of Table) (FEMA, 1983).

3. **National Flood Insurance Program**. This program was created in 1968 to:-make flood insurance available to property owners already located in flood prone areas, and encourage state and local governments to institute land use management that reduces development in flood hazard areas.

The Federal Emergency Management Agency administers this program. To participate, a community must adopt a program that includes subdivision regulations, floodway area restrictions, and elevation requirements to discourage unwise development. These may be considered both preventive and corrective techniques. Communities enrolled in the National Flood Insurance Program are eligible for technical and financial assistance in reconstructing their flood-damaged properties (FEMA, 1981).

4. **Comprehensive Community Planning**. Floodplain management and flood hazard mitigation should be an integral part of the community comprehensive planning and development process. The basic responsibility for regulating floodplain use lies with state and local governments. Many local comprehensive land use plans have been developed without consideration of drainage ways and floodplains. A flood disaster impacts and is impacted by every aspect of community life and planning, housing, public services, utilities, commerce, and major streets. Therefore, there is a direct relationship between flood disasters and comprehensive community planning (FEMA, 1981).

5. **Regulations to Control Floodplain Development**. Floodplain regulations represent a legal mechanism used to control development in the floodplain in an effort to reduce flood damage. This is accomplished by restricting development in hazardous areas and/or by providing performance standards for construction there. Some potential floodplain regulations are listed below:

Floodplain Ordinances Local governments are required to adopt land use regulations that restrict land use within designated floodplains. If these adopted regulations meet minimum state and federal standards and are actively enforced, they serve as an effective tool to mitigate flood hazards (Montana Disaster & Emergency Services Division, 1986).

Zoning "Zoning divides the area under the jurisdiction of a government unit into specified areas for the purpose of regulating (a) the use of structures and land, (b) the height and bulk of structures, and © the size of lots and density of use." This tool may be used to regulate land use in flood hazard areas (e.g., specification of minimum floor elevation) (FEMA, 1981).

Subdivision Regulations "Subdivision regulations guide the process of land division to assure that lots are suitable for intended use without putting a disproportionate burden on the community." They often require (a) installation of adequate drainage, (b) delineation of flood hazard areas on the plat, © avoidance of encroachment into floodplain areas, © determination of the most suitable means of elevating a building above potential flood height, and (e) consideration of the selected flood protection elevation when situating streets and public utilities (FEMA, 1981).

Building Permits and Codes Building codes dictate building design and use of construction materials. They can reduce structural flood damage by such means as: (a) requiring adequate anchoring to prevent mobile home flotation during floods, (b) setting minimum protection elevations for the first floor of structures, © requiring use of building materials that will not deteriorate when wetted, etc.

Soil Erosion and Sedimentation Control Although they are natural occurrences, soil erosion and sediment deposition can inhibit floodwater carrying capacities of channels, bridges, and conduits increasing the possibility of flooding adjacent areas. Sediment control is practiced to prevent or reduce deposition damage both on and off the development site. Construction of sediment settling basins is one technique for mitigating this problem. Effective erosion control techniques include securely anchoring railroad ties to the slope, the placing of rip-rap (large broken rock) or the use of gabion (groups of rock bundled together with wire) (FEMA, 1986).

Storm water Runoff Controls Storm water runoff regulations can require on-site storm water detention/retention ponds for new development. The purpose of these regulations is to require that flood flows be directed to catchments basins in an effort to counteract the increase in flood peak heights which result from reducing the ground surface available to absorb storm water runoff.

Drainage and Flood Control Criteria. Improperly designed drainage structures and the failure of those structures (bridges, channels, culverts, and embankment protections) often cause flood damage. Urban drainage and flood control criteria may be developed as a separate manual or handbook, or included in the community subdivision regulations. Public agencies and design engineers will use these criteria.

Master Drainage way planning. The goal of master drainage way planning is to reduce the flood hazard in a specific drainage basin or floodplain. Steps involved in the development and implementation of a master drainage plan include data collection (land uses; drainage routes; hydrology; capacities of existing facilities, floodplain limits; and impacts on adjacent properties), conceptual design (development and review of all reasonable alternatives), and master planning (describes in detail the recommended alternative).

Public Acquisition of Flood prone Lands. There are generally two types of acquisition of undeveloped flood prone lands: a) purchase of fee title; and b) acquisition of land use easement (FEMA, 1981). Once acquired, some of the beneficial aspects of flooding may be realized. Benefits of flooding and floodplains include the natural storage of floodwaters, filtering or dilution of pollutants which enter the waterways, flushing of nutrients in river systems, preservation of wetlands, decreasing runoff having direct access to the waterway, enhancement of recreational opportunities, recharging of groundwater, and maintaining the river ecosystem by providing breeding, nesting, feeding and nursery areas for fish, migrating waterfowl and others (National Science Foundation, 1980). The technique of public acquisition assures that flooding will damage no future structural development. Acquisition of flood prone lands is more expensive than regulating their use, however, acquisition may well be less expensive than structural protection of these areas or rehabilitation following a flood event (FEMA, 1981).

Community Policy Regarding Provision of Public Facilities and Utilities in Floodplain Areas (Capital Improvements Planning). Comprehensive ordinances can specify the design and location of public facilities such as water and sewer distribution systems, to minimize the risk of contamination or damage during floods (National Science Foundation, 1980).

Corrective Techniques

1. **Acquisition and Relocation**. In the event that a floodway is already developed, floodplain areas may be obtained by outright purchase or by purchasing selected development rights. (National Science Foundation, 1980). This action not only serves to break the cycle of damage and rebuilding, but also helps property owners who would like their structure to be bought out, demolished or relocated. Since the cost of this technique is often high, it usually can only be justified when the situation is especially urgent or it serves other community goals (FEMA, 1981 and National Science Foundation, 1980).

TYPES OF PROPERTY ACQUISITION

Generally, we can divide property acquisitions into two broad categories: basic acquisition and acquisition and relocation of structures.

- **Basic Acquisition**: A basic acquisition project simply acquires land and structures, and demolishes the structures located on the land. It is conducted like any other real estate transaction, and is the easiest type of acquisition project to implement and manage.
- **Acquisition and relocation of structures**: An acquisition and relocation project is a basic acquisition that acquires land, but offers an alternative to demolishing structures: moving them out of harm's way, outside the floodplain. Relocation might mean simply moving a structure to another lot, or reestablishing an entire neighborhood at a new site within the community. A structure can be relocated on the same property if a portion of it is outside the floodplain. Relocation often is a good way to protect historic structures.

METHODS OF PROPERTY ACQUISITION

- **Fee-Simple acquisition*:*** Fee-simple acquisition simply means acquiring title to land and structures. By law, restrictions must be attached to the deed. Restrictions include the following:
  - The property shall be dedicated and maintained in perpetuity for uses compatible with open space, recreational, or wetlands management practices.

  - No new structures will be built on the property except for the following:

    - A public facility open on all sides and functionally related to a designated open space or recreational use,
    - A public rest room that is wet flood proofed; or
    - A structure compatible with open space, recreational, or wetlands management use and proper floodplain management policies and practices, which FEMA's Director approves in writing before construction of the structure begins.

- **Acquisition of a conservation easement:** Conservation easements are practical in agricultural areas where the owner wants to retain title and continue farming his or her property. It also is practical where acquiring a large parcel of property is cost prohibitive. Simply defined, an easement is a right of passage over someone else's land. However, an easement can be used to prevent the owner from doing certain things. A conservation easement is an easement that prevents the property owner from developing the property. The property owner retains title to his or her property and can transfer title. However, the terms of a conservation easement acquired using FEMA Mitigation funds carry the same restrictions as fee-simple acquisition, and the property is forever subject to those terms, regardless of who has the title.

2. **Flood proofing**. The term flood proofing may be applied to any measure taken to reduce the vulnerability of an individual structure and its contents to flood damages. These might include: a) measures that prohibit floodwaters from entering a building, or b) utilizing space and specialized materials to reduce damages from water which enters a building. Facilities other than buildings (bridges, roads, docks, etc.) may be flood proofed with additional anchoring, rip rap protection against erosion, bank stabilization through re-vegetation, etc. (FEMA, 1981).

3. **Structural Elevation**. This mitigation technique involves raising the lowest floor of a structure above the base flood level through methods such as earth fill, concrete walls, and wood, steel or concrete posts, piles or piers. Elevation on posts or piles is the preferred method since floodwaters can flow relatively unimpeded under the structure thus reducing the likelihood of damage to adjacent properties (FEMA, 1981).

4. **Floodwalls and Levees**. Floodwalls and levees are embankments or structures generally less than six feet high designed to keep floodwaters from inundating one or several structures (FEMA, 1981). They may often be incorporated into the landscaping of a home without altering the structure.

5. **National Flood Insurance Program**. (discussed under preventive techniques.)

6. **Local Hazard Mitigation Planning**. It is advisable for all jurisdictions, especially those that frequently suffer disaster damage to develop Local Hazard Mitigation Plans. Projects should be developed and maintained until such time as a Presidential Declaration or other such funding may become available.

7. **Flood Forecasting and Warning Systems**. Flood forecast and warning systems provide information concerning expected flood size arrival time (FEMA, 1981). Coordinated systems can lead to substantial reduction of property damage and loss of lives (National Science Foundation, 1980).

Structural Mitigation

Structural flood mitigation measures include channel modification, flood control storage reservoirs, pumping stations, bridge and culvert improvements, levees, floodwalls and dikes and other engineering approaches to controlling flood waters in order to protect man-made development from damage. Since these measures are generally well understood and programs to implement them are already sponsored by several agencies (e.g., U.S. Army Corps of Engineers, Soil Conservation Service, Tennessee Valley Authority, and the U.S. Bureau of Reclamation) they will only be briefly discussed here (FEMA, 1981).

1. **Channel Modification**. Stream channel capacity may be increased by deepening, widening or straightening the stream or by removal of obstructions. Such modifications may increase flooding downstream since they almost always reduce natural valley storage (National Science Foundation, 1980).

2. **Flood Control Storage Reservoirs**. A storage reservoir is a stream impoundment with outlets that may be controlled. Adequate storage capacity and emergency spillway capacity are essential to minimize the possibility of dam failure (National Science Foundation, 1980).

3. **Pumping Stations.** Sump pumps should be installed in the lowest areas inside a levee to ensure that water from precipitation or seepage is removed during flooding. The pump should have an independent power source in case there is an interruption of electrical power during flooding (FEMA, 1986).

4. **Bridge and Culvert Improvements**. Bridges and culverts should be upgraded to handle maximum predicted flood flows. Inadequate structures may have the effect of restricting flood flows thus increasing flood heights and velocities downstream (Jim E. Richard Consulting Services et al, 1986).

5. **Levees, Dikes and Floodwalls**. The term levee and dike are both used to describe a long low embankment whose height is usually less than 12 to 15 feet and whose length is more than 10 or 15 times the maximum height. The terms are usually applied to embankments or structures built to protect land from flooding. If built of concrete or masonry, the structure is usually referred to as a floodwall. A floodwall, which is a more compact structure than a levee, is normally constructed where sufficient land area required for levee construction is either expensive or not available (Colorado Department of Public Safety, 1986).

Structural mitigation measures generally provide short-term solutions and are not always a cost-effective means of dealing with the problem. Non-structural measures usually offer long-term solutions but may not adequately address an immediate threat. Administrative costs may be high for non-structural measures (Jim E. Richard Consulting Services et al, 1986). Combining both structural and non-structural techniques is the most effective approach to flood mitigation (FEMA, 1981).

6. **Dam Failure Mitigation**

Several of the mitigation techniques listed above may also minimize the risk and reduce the damages due to dam failure. Measures that should be addressed as they relate to dam failure mitigation include public education, legislation, emergency planning, and insurance.

7. **Public Education**

The public must be made aware of dam safety problems. Information to be distributed might include a listing of which dams are considered unsafe, where they are located, what the leading causes of dam failure are and what preventive actions can be taken.

8. **Legislation**

Dam safety rules require that specific guidelines and standards be followed in the design, construction and maintenance of dams with an impoundment capacity of 50 acre-feet or greater. These rules also require that any high hazard dam (the failure of which would likely cause loss of life within the flooded area) maintain a plan of operation for normal, flood, and emergency conditions. This plan should include operation procedures, maintenance procedures, and emergency procedures and warning plan (DNRC, 1987).

9. **Emergency Warning or Preparedness Plans**

These plans provide detailed information on measures to be taken to protect lives and property in the event of dam failure. Inundation maps, which delineate the area affected by potential floodwaters, serve as the basis for planning. Lists of individuals to be notified or evacuated should be included and updated in any plan.

10. **Group Insurance Plans**

Group insurance policies for dam owners would spread the insurance cost of coverage for economic losses caused by dam failure over an entire group of dam owners in a particular area. The risk of dam failure continues to increase as dams deteriorate over the years and as development continues to disregard the potential hazard. Montanans must be made aware of the problem and encouraged to alleviate it before a tragic dam failure occurs (LaFrance, 1984). Further research is needed in the following areas to enhance future flood/dam failure planning efforts:

1. Comprehensive storm water management measures that are economically, environmentally and socially cost-effective (National Science Foundation, 1980).
2. Improvement of methods of estimating flood flows (White, 1975).

3. Coordination of irrigation storage and flood control uses of reservoirs such that the reservoir capacity can withstand the added volume of flow in the event of a flood (Henry, 1987).
4. Solution of problems concerning the functioning of warning systems and increased funding for the application of known techniques for more effective flood warnings (White, 1975).

G. SUMMARY

Montana is subject to three principal types of flooding: riverine flooding, flash flooding and dam failure flooding. Because many Montanans have chosen to locate in flood hazard areas, all three flood types have historically had damaging effects. As long as people continue to develop in these areas, whether knowingly or unknowingly, flood events will continue to take their toll.

Flood mitigation strategies should combine both structural and non-structural approaches to alleviating the hazard. Structural approaches include reservoir storage, channel modification, levees (dikes) and floodwalls, pumping stations and other engineering works designed to control floodwaters. Non-structural approaches include both preventive and corrective actions. Preventive actions involve comprehensive floodplain management techniques that prevent unwise and hazardous development of the floodplain. Corrective actions are directed at mitigating flood damages and losses, which result from unwise development of flood hazard areas.

In addition to the above mentioned techniques, dam failure flooding may be mitigated through dam safety legislation, effective emergency warning or preparedness plans, group insurance plans for dam owners and increased public awareness of dam safety problems.

The flood hazard in Montana will never be subject to complete control by man but damaging effects can be substantially mitigated.

H. RECOMMENDATIONS: Recommendations for this Hazard are found in Annex X Flood, pages J-8 through J-34, to this plan.

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